Data Assimilation with AIRS in Storm-Scale Models, Error Estimation and Smoothing

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Goals

- Improve short-term numerical prediction of high impact weather events such as severe thunderstorms and flash floods using data from the AIRS/AMSU and AMSR-E instruments on the Aqua satellite.
- The Aqua satellite's ability to obtain data over the Gulf of Mexico promises to improve forecasts of air mass modification and return moisture flow from the Gulf.
- Study surface cyclogenesis in and near the Gulf of Mexico.

Research Plan

- Become familiar with AIRS and AMSR-E data qualities
- Investigate use of AIRS and AMSR-E data using existing tools
- Use AIRS retrieved soundings directly
- Modify use of AIRS in ADAS to match effective vertical resolution
- Use AIRS radiances in 3DVAR system

Data Assimilation Using ADAS

- ARPS Data Analysis System (ADAS) used to assimilate AIRS retrieved sounding data in a high-resolution nonhydrostatic model.
- ADAS is a Bratseth successive correction statistical analysis that converges to optimal interpolation.
- Flexible system of ingesting data having varying sources and observation densities.
- Error characteristics of the data can be specified by each source and by height above ground level.
- Includes complex cloud analysis procedure that integrates cloud information from surface stations, visible and IR satellite data, and radar reflectivity.

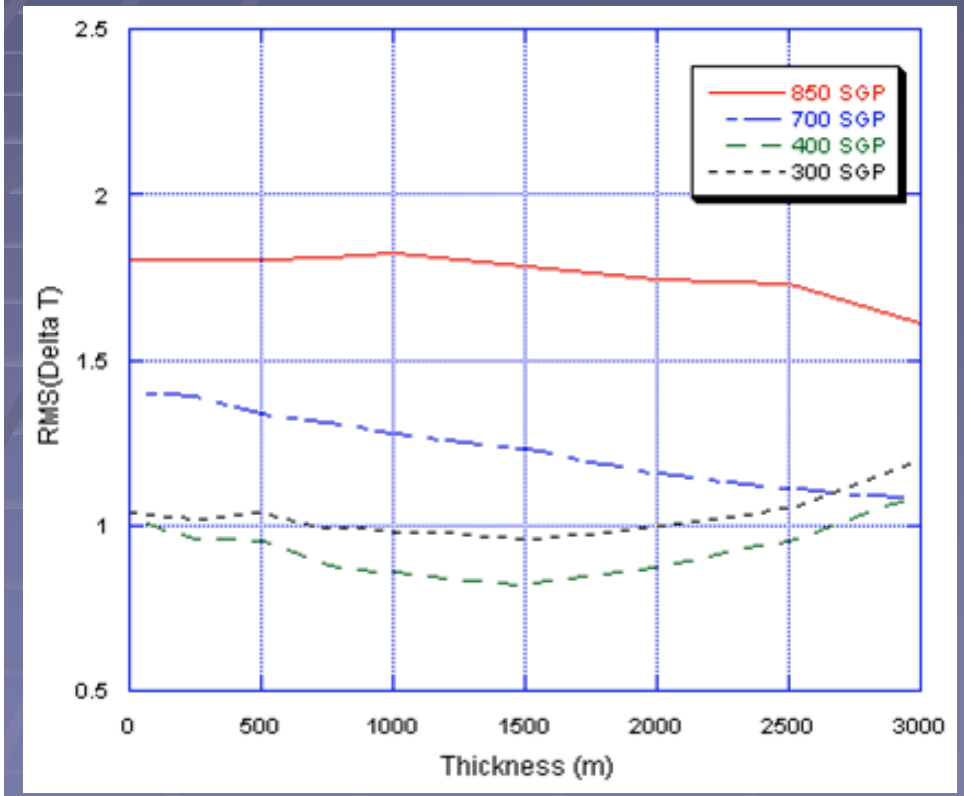
Data Error Statistics

- ADAS requires error files for each of the data types it ingests.
- Use comparison project soundings:
- Atmospheric Radiation Measuring Program (ARM) Southern Great Plains site (SGP) at Lamont, Oklahoma (Land)
  - August 29, 2005 to October 17, 2005
- Tropical Western Pacific (TWP) ARM site (Ocean)
  - September 16, 2005 until the end of December 2005.

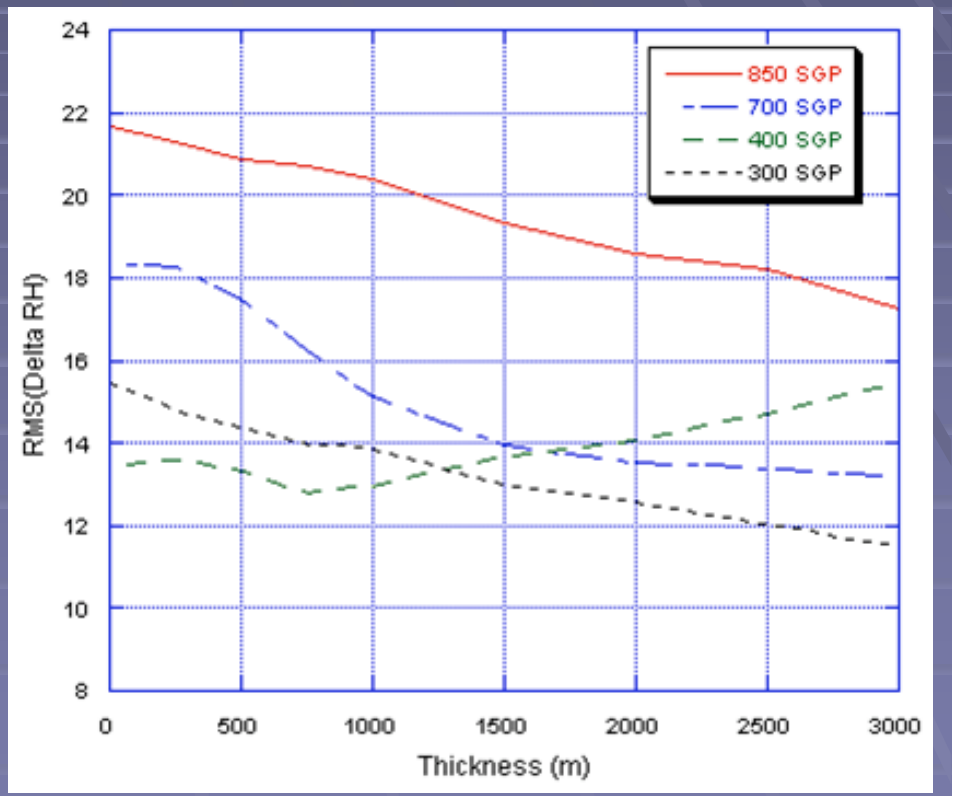
Comparison Sounding Filtering

- AIRS retrievals are reported as point observations, but due to the nature of the radiation measurements the values given are representative of layer averages.
- Objective: determine if filtering of background field needed before computing observation increments
- Compared AIRS with layer averages of ARM SGP and TWP data. Big caveat: Nearest neighbor used.
- Average over layers of varying thickness to determine which fits best.
- Also tried applying a Barnes filter to the ARM soundings

Layer Average SGP

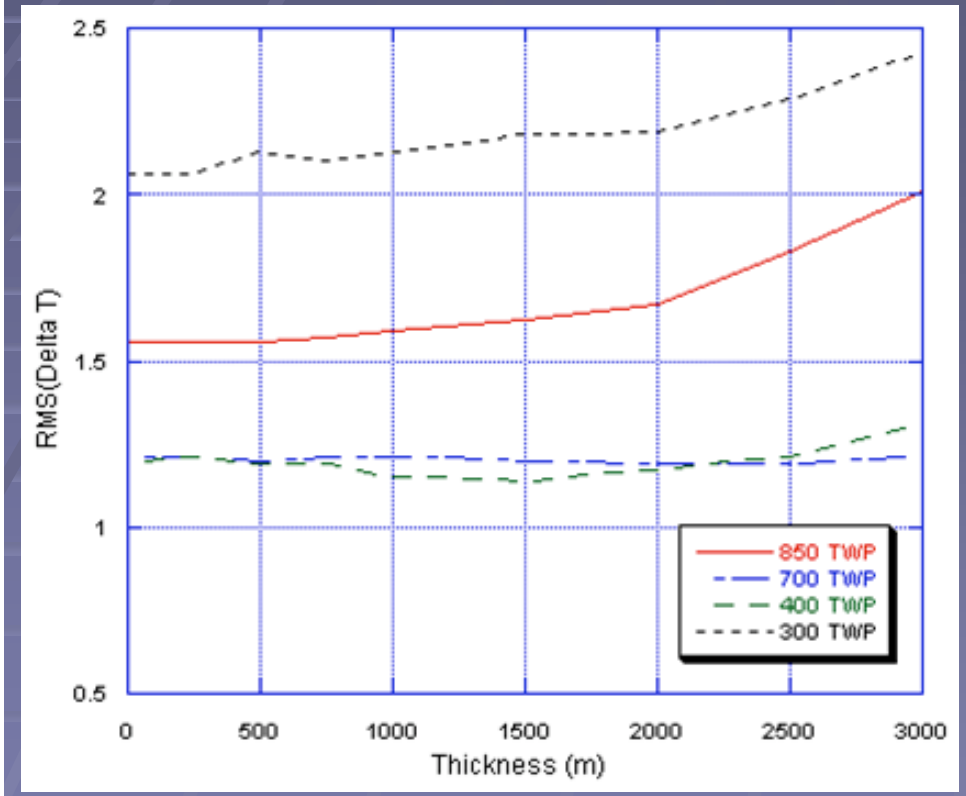


Temperature

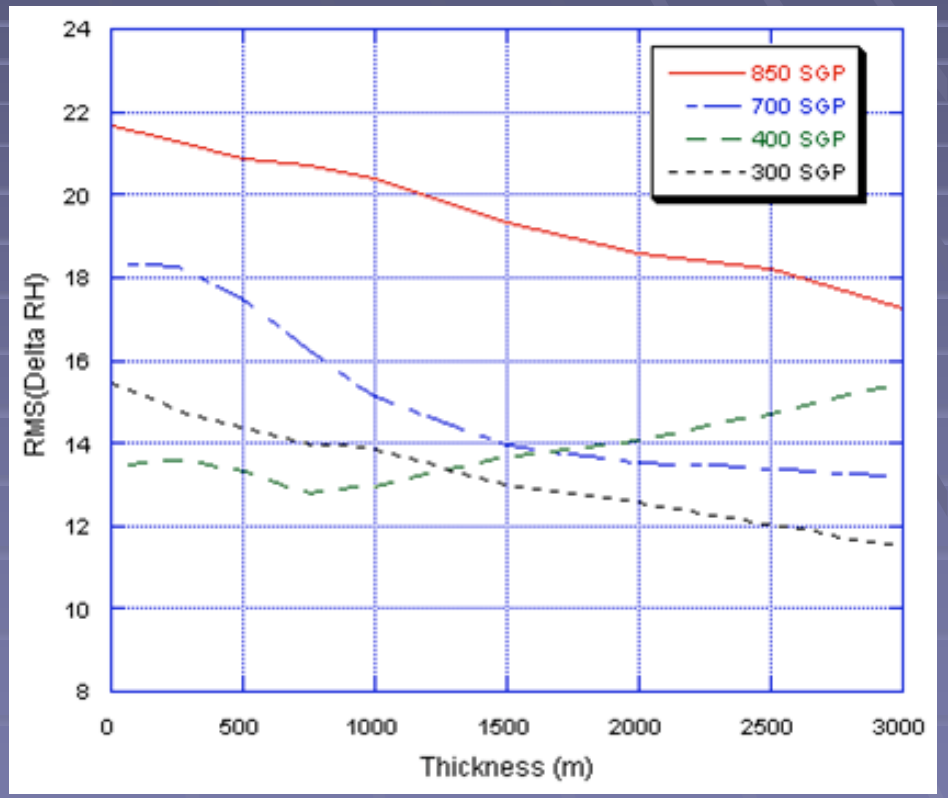


Relative Humidity

Layer Averages TWP



Temperature



Relative Humidity

Barnes Filter Weighting

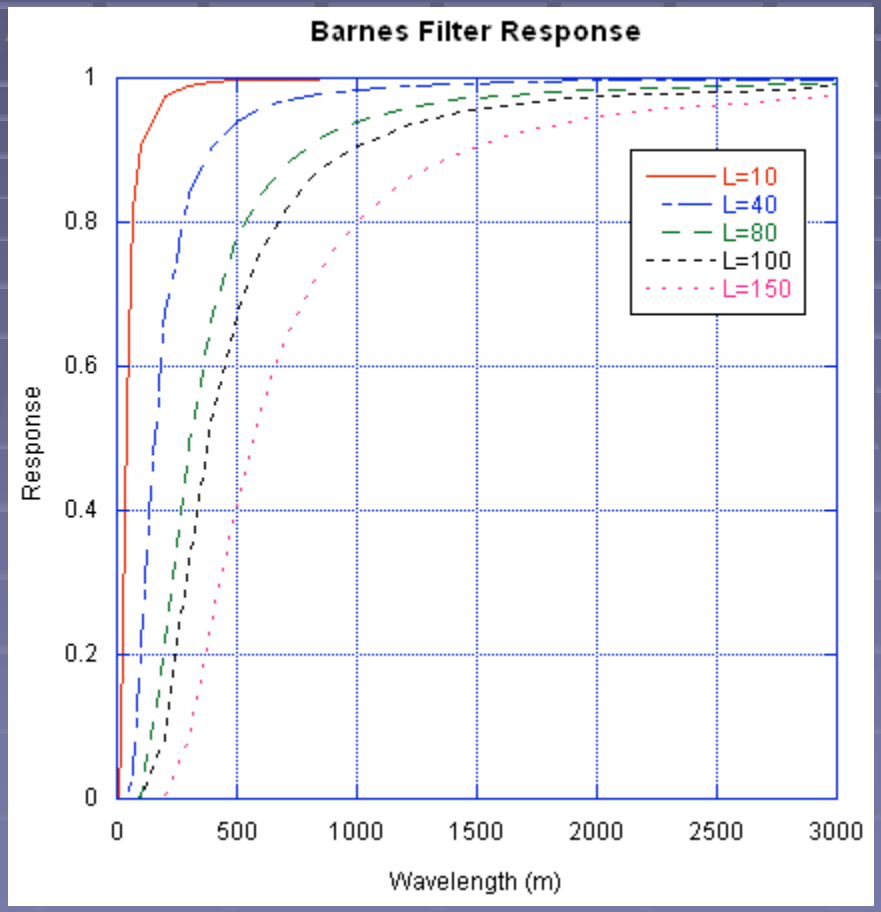
- Replace layer averaging with a weighted average filter that has a known response function. Weights:

$$w_m = \exp\left(-\left(z_m - z\right)^2 / L^2\right)$$

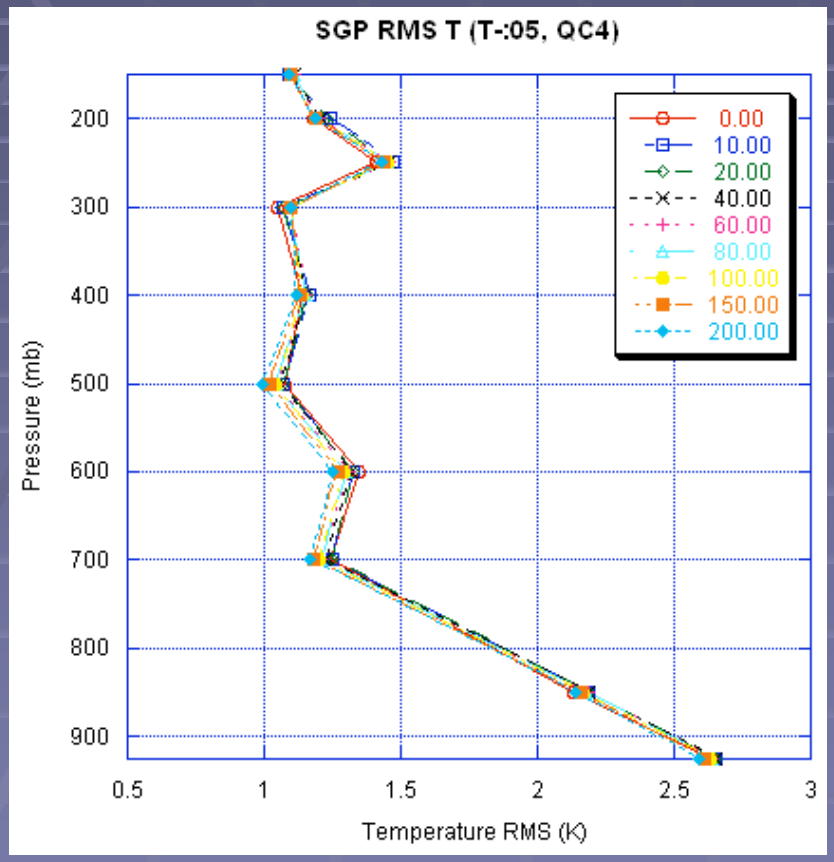
Response:

$$R(\lambda) = \exp\left(-L^2\pi^2 / \lambda^2\right)$$

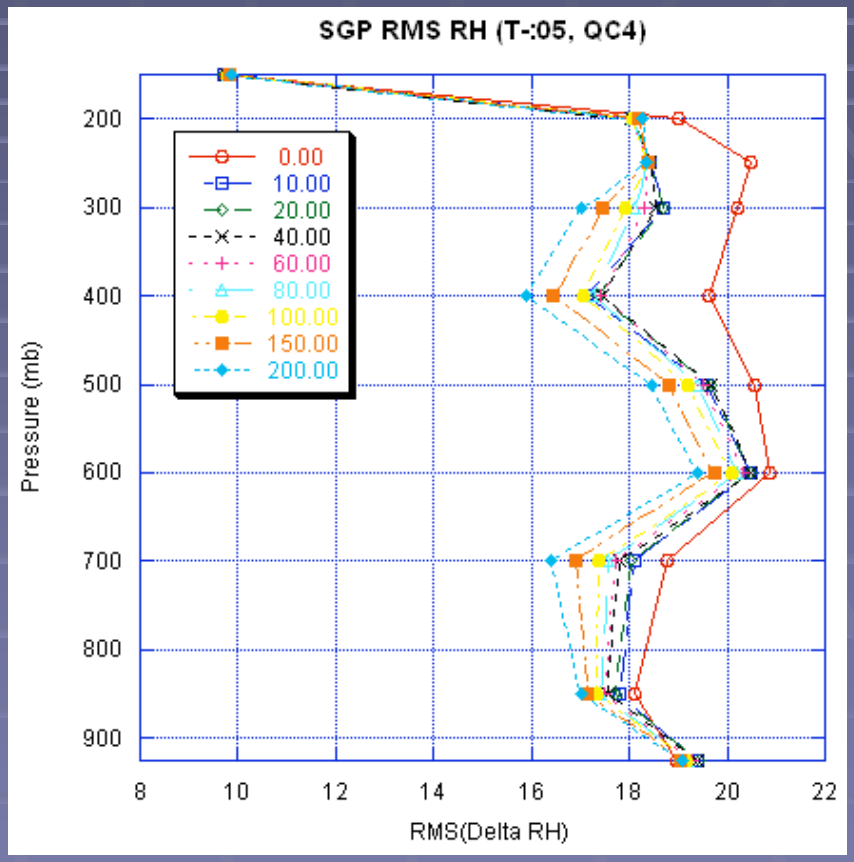
Response Curves



Barnes Filter Testing

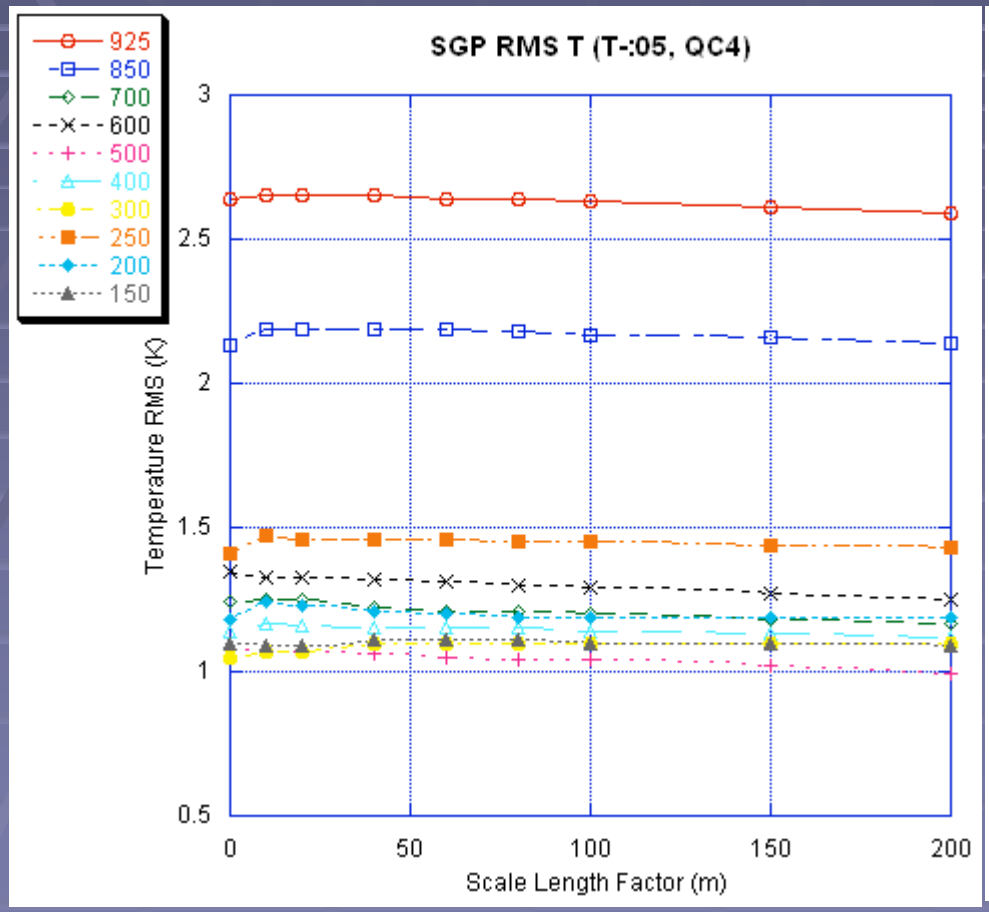


Temperature at SGP

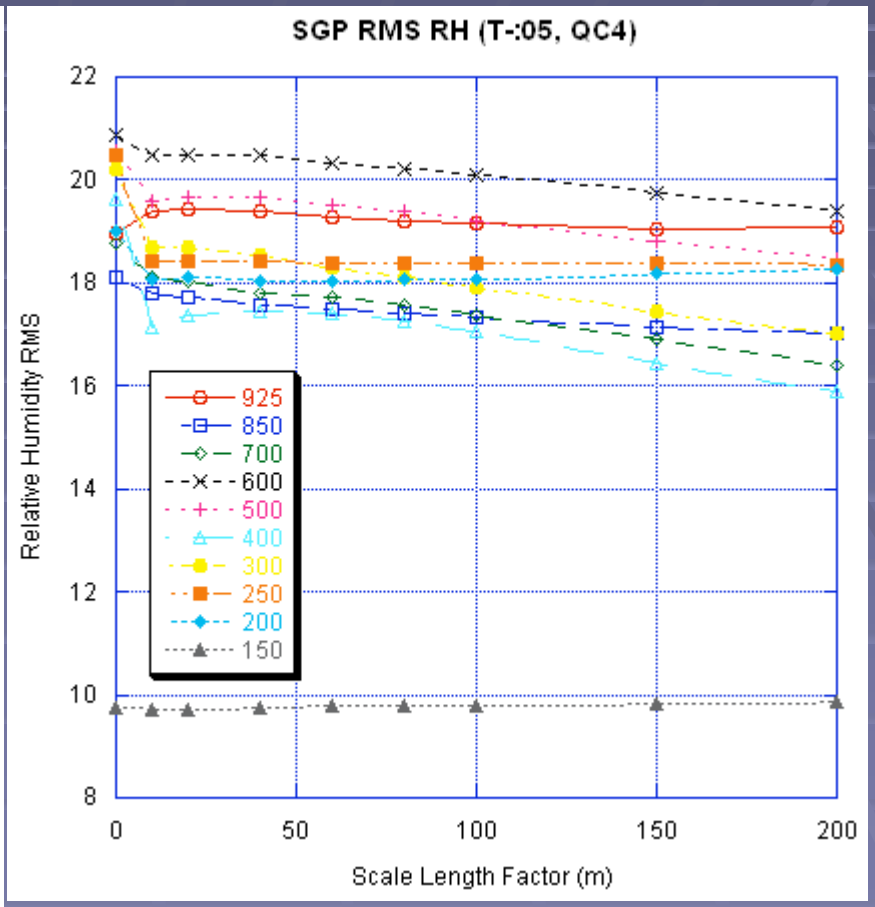


RH at SGP

Barnes Filter Testing



Temperature

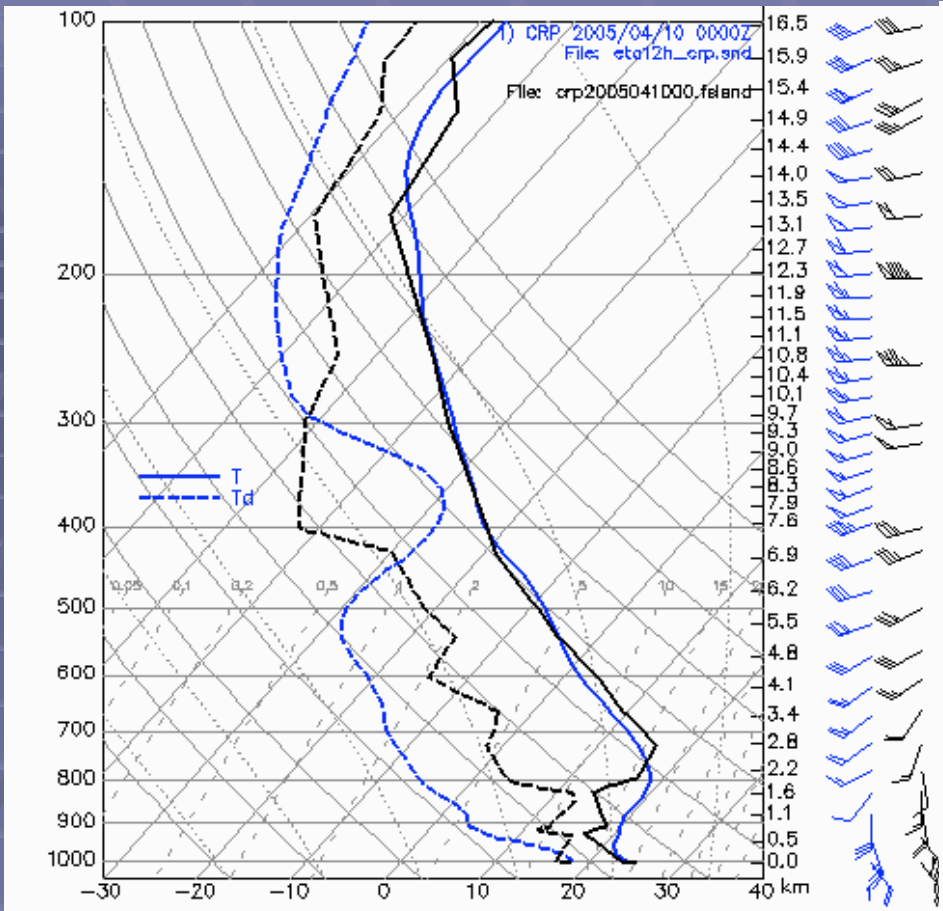


Relative Humidity

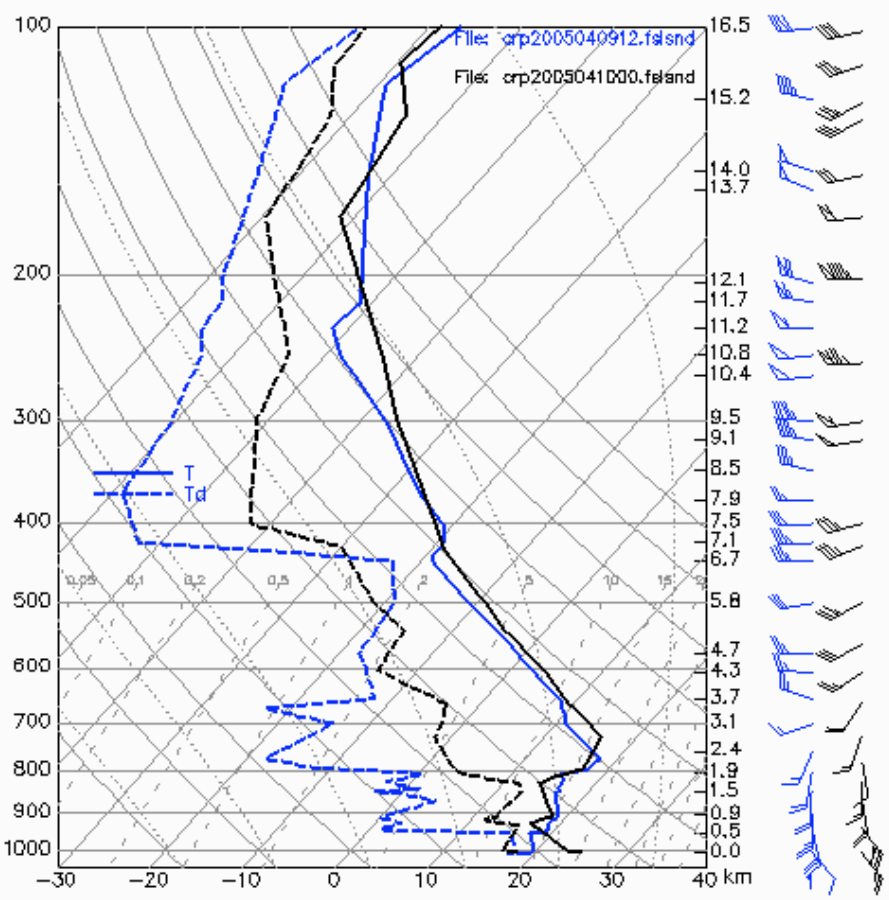
09-10 April 2005 Case

- NWS rawinsonde observation at Corpus Christi, Texas at 00 UTC on April 10, 2005 had 11 g/kg of water vapor at 850 mb compared to only 5 g/kg forecast by 12-h NAM from 12 UTC.

- Air mass modification and return flow from the Gulf of Mexico could have influenced the severe thunderstorm outbreak that occurred on the afternoon of April 10 in Central Texas to Oklahoma.

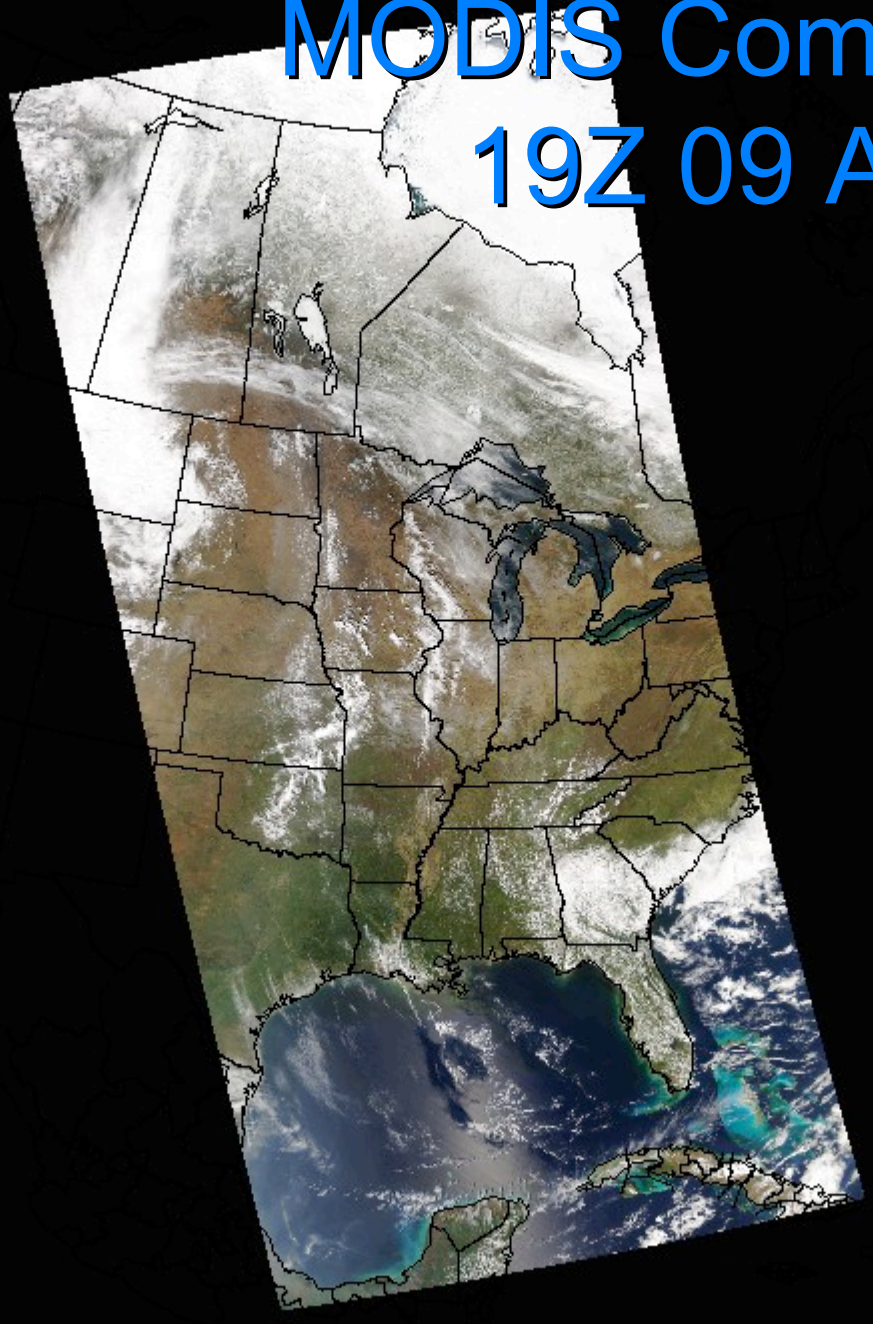


CRP Obs (Black) vs
12-h NAM (Blue)
00z 10-April-2005



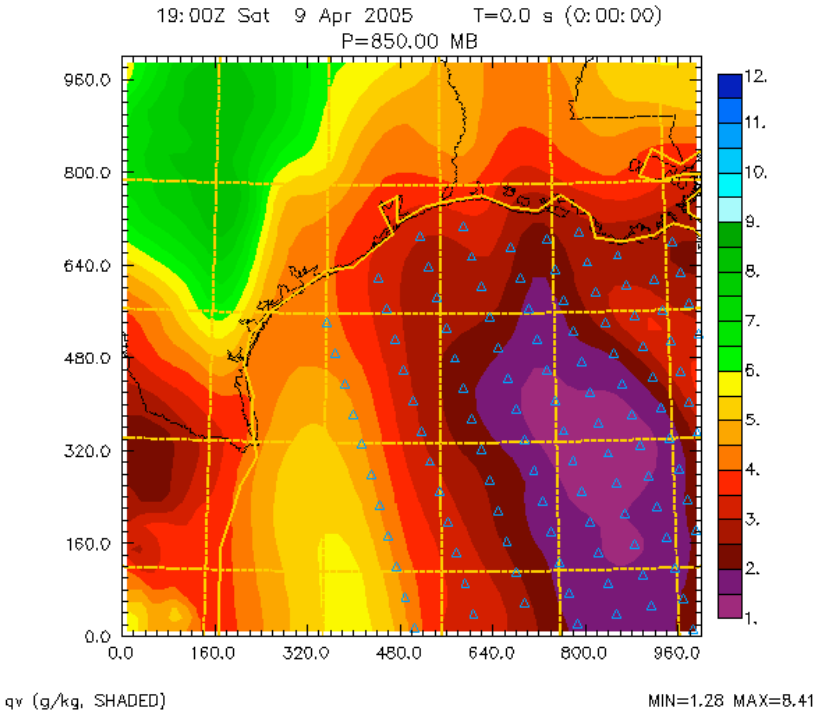
CRP 00z 10 April (Black) vs
CRP 12z 09 April (Blue)

MODIS Composite Imag
19Z 09 April 2005

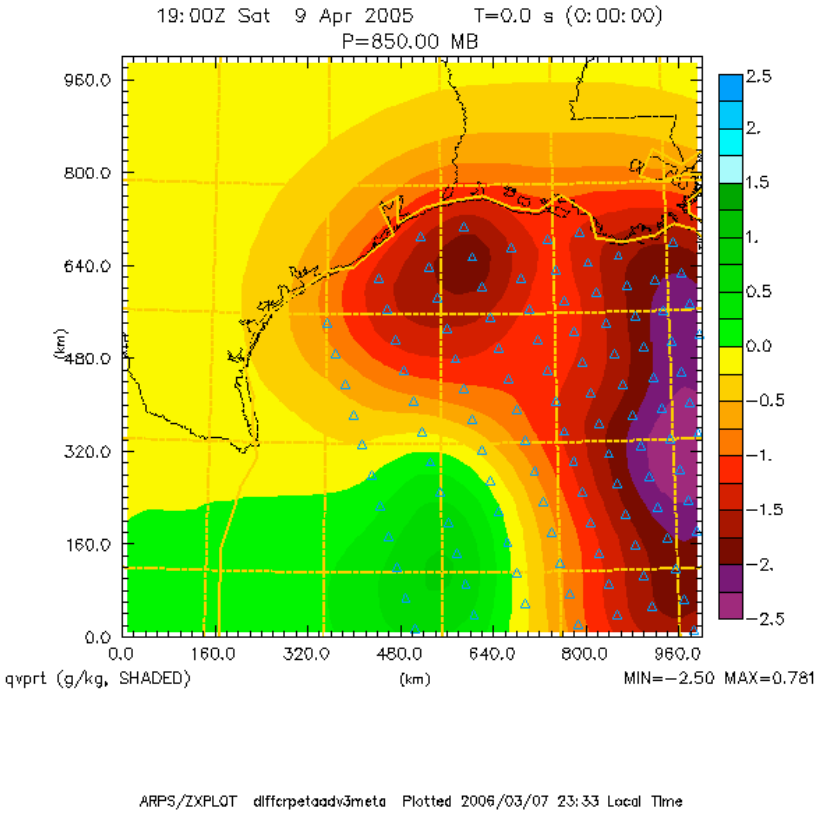


AIRS Sounding Moisture Analysis

850-mb qv Analysis

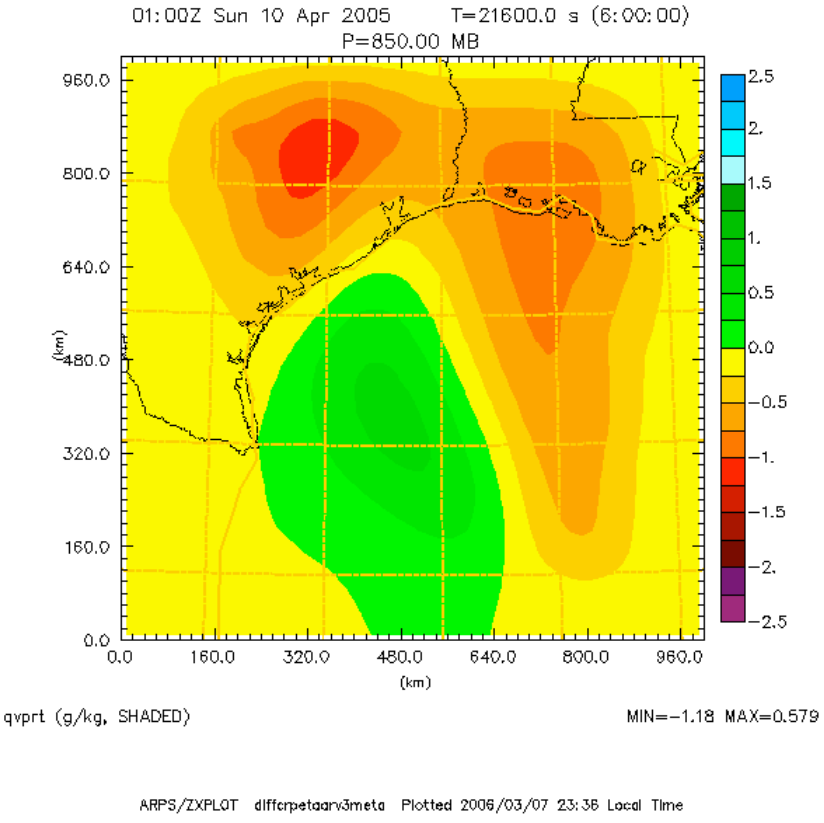


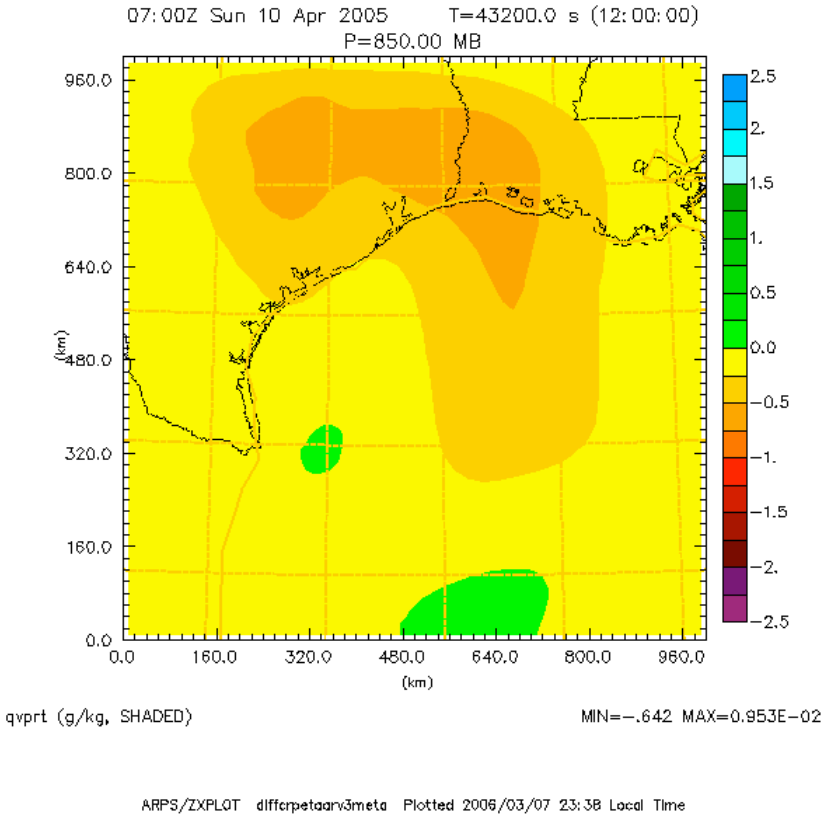
AIRS Impact



Forecast 06 h and 12 h

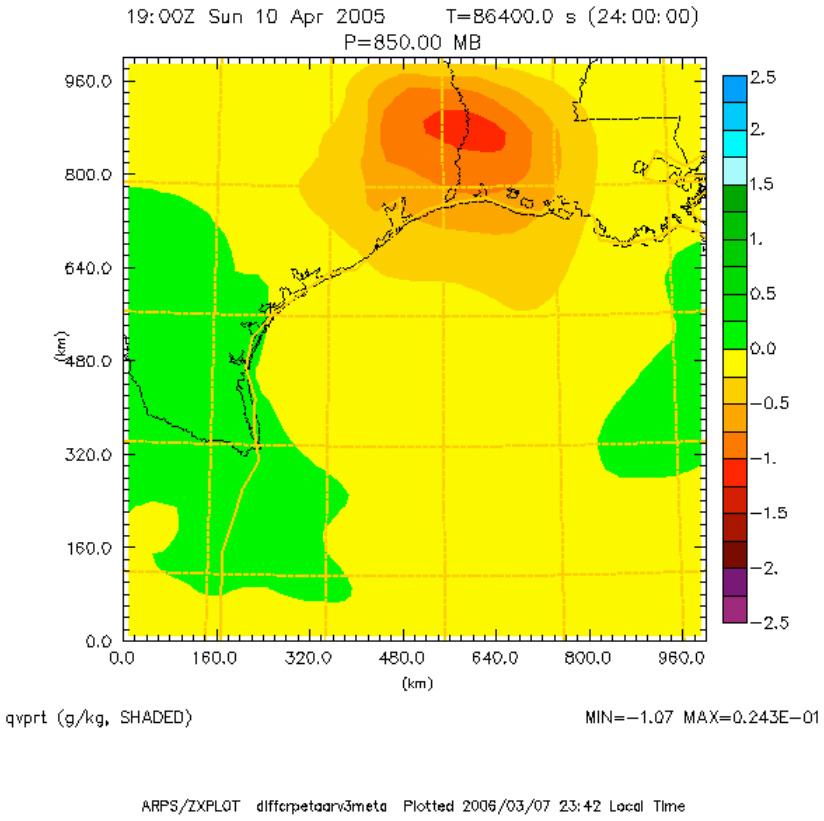
AIRS Impact





Forecast 24-h

AIRS Impact



Analysis Results

- Comparison made between ADAS analysis including AIRS data and ADAS analysis without the AIRS data
  - AIRS profiles dried out the region right off the coast of Texas/Louisiana by about 1.75g/kg.
  - Further to the south there was a moisture increase around 0.5g/kg.

- ARPS model used to produce a 24 hour forecast.

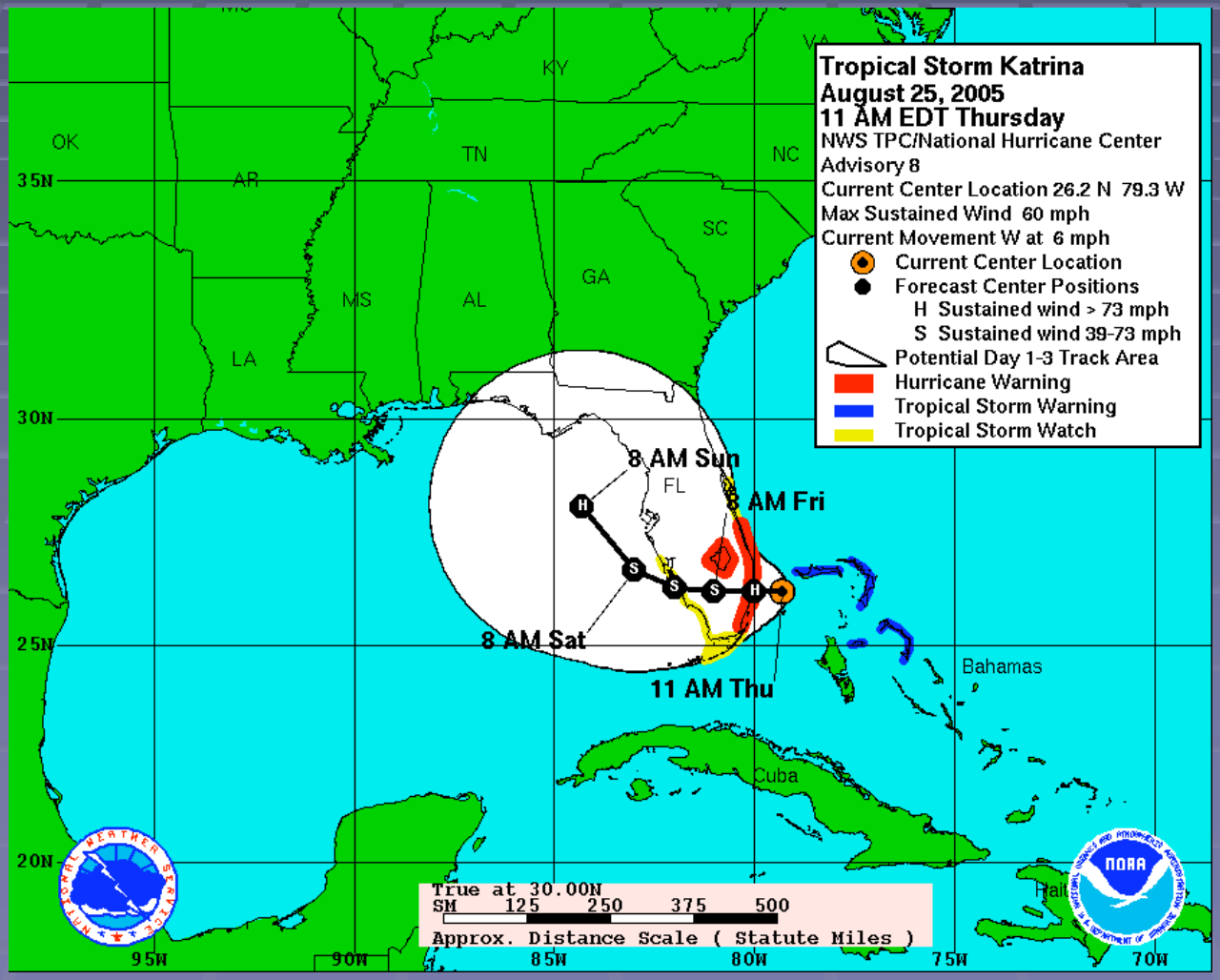
  - AIRS data contributed to a 0.5 g/kg moisture increase just off the Texas coast.

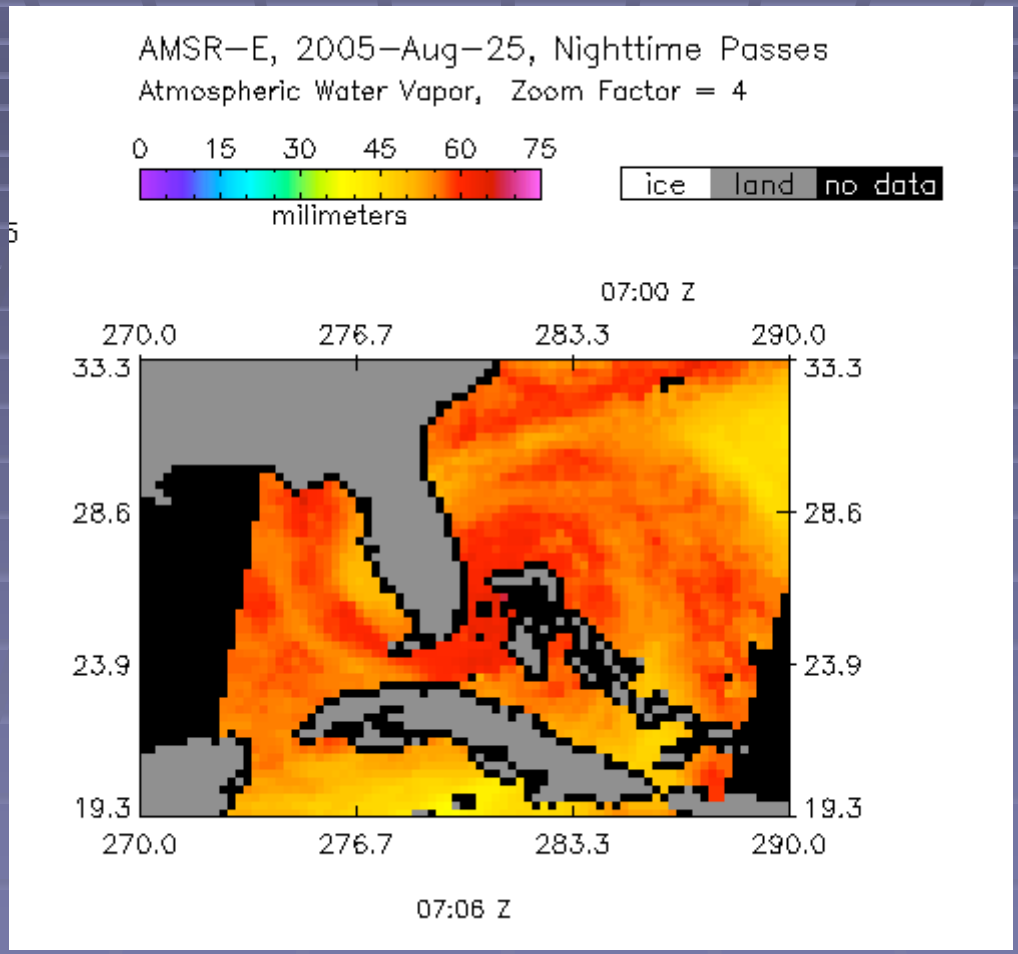
  - There is a moisture decrease of 1.0 g/kg north and east of the region of moisture increase.

  - Results at 12 and 24 hours shows a smaller impact.

  - No significant difference between the background field was noticed after 12 hours.

Candidate Case
Early Katrina: 25 August 2005




AMSR-E, 2005-Aug-25, Nighttime Passes
Atmospheric Water Vapor, Zoom Factor = 4
0 15 30 45 60 75
milimeters
ice
land
no data
07:00 Z
270.0
276.7
283.3
290.0
33.3
28.6
23.9
19.3
07:06 Z

3DVAR Work Starting

- Worked with CRTM group to gain access to code.
- CRTM currently in NCEP GSI
- Will be implementing CRTM in ARPS 3DVAR

Summary

- AIRS data (Ocean) impact demonstrated for one case for Gulf Coast
- Separately had success in using AMSR-E precipitation data to expand range of coastal radars
- Simple data error statistics used, continuing efforts to refine
- Will be combining both techniques in another case study using ADAS, then testing 3DVAR